COLLEGE OF ENGINEERING
PUTRAJAYA CAMPUS
FINAL EXAMINATION

SEMESTER 2 2018 / 2019

MODEL ANSWERS

PROGRAMME	: **Bachelor of Electrical & Electronics Engineering (Honours)** **Bachelor of Electrical Power Engineering (Honours)**
SUBJECT CODE	: **EEEB273/EEEB2014**
SUBJECT	: **ELECTRONIC ANALYSIS AND DESIGN II**
DATE	: **January/February 2019**
TIME	: **3 hours**

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **FIVE** (5) questions in **TEN** (10) pages.
2. Answer **ALL** questions.
3. Write **all** answers in the answer booklet provided. **Use pen** to write your answer.
4. Write answer to different question on **a new page**.

THIS QUESTION PAPER CONSISTS OF TEN (10) ***PRINTED PAGES INCLUDING THIS COVER PAGE.***

Question 1 [20 marks]

Answers:

Q1(a) **Calculate** the percentage change in output current I_O. **[8 marks]**

$R_O = r_{O2}[1 + g_{m2}(r_{\pi 2}||R_E)]$ [1]

$r_{O2} = \frac{V_A}{I_O} = \frac{200}{20\mu} = 12.5\ M\Omega$ [0.5]

$g_{m2} = \frac{I_O}{V_T} = \frac{20\mu}{26m} = 0.7692\ mA/V$ [0.5]

$r_{\pi 2} = \frac{\beta V_T}{I_O} = \frac{200(26m)}{20\mu} = 260\ k\Omega]$ [0.5]

$R_E = \frac{V_T}{I_O}\ln(\frac{I_{REF}}{I_O}) = \frac{26m}{20\mu}\ln(\frac{0.5m}{20\mu}) = 4.1845\ k\Omega]$ [1]

$R_O = 12.5M[1 + 0.7692m(260k||4.1845k)] = 52.05\ M\Omega$ [1]

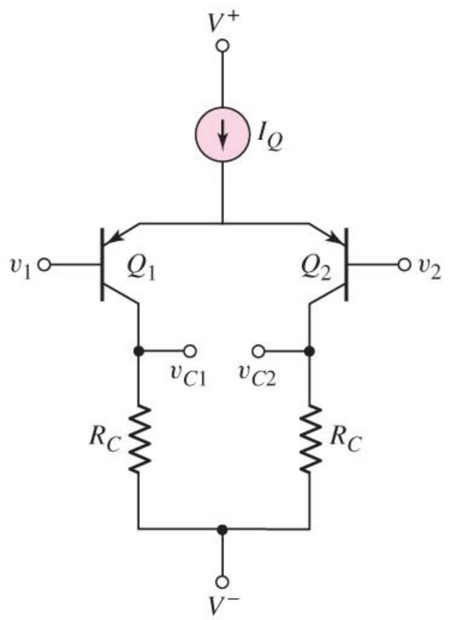
$dI_O = \frac{dV_{C2}}{R_O} = \frac{20\mu}{26m} = 0.7692\ mA/V$ [1]

$dV_{C2} = 5 - 0.9 = 4.1\ V$ [0.5]

$dI_O = \frac{dV_{C2}}{R_O} = \frac{4.1}{52.05M} = 0.0787\ \mu A$ [1]

Percentage change in $Io = \frac{dI_O}{I_O}x100\% = \frac{0.0787\mu}{20\mu}x100\% = 0.394\%$ [1]

Q1(b) **Draw pnp diff amp** **[4 marks]**



Correct location of devices:

current source, transistors & load Rc [1 + 1 + 1]

Correct connection to power supplies [1]

Q1(c) **Calculate** max value of load resistance $\boldsymbol{R_C}$ and one-sided differential gain, $\boldsymbol{A_d}$. **[8 marks]**

$V_E = V_{EB}(on) + V_B = 0.7 + 0 = 0.7\ V$ **[1]**

Also, $V_E = V_{EC} + V_C = V_{EB}(on) + V_C = 0.7 + V_C = 0.7\ V$ **[1]**

So, $V_C = 0\ V$ **[0.5]**

$V_C = I_{C1}R_C + V_-$ **[1]**

$I_{C1} = \frac{I_Q}{2} = \frac{0.5m}{2} = 0.25\ mA$ **[0.5]**

Thus, $V_C = 0 = (0.25m)R_C + (-5)$ ➔ $\boldsymbol{Rc}$ = 20 kΩ **[1]**

$A_d = \frac{g_m R_C}{2}$ **[1]**

$g_m = \frac{I_{C1}}{V_T} = \frac{0.25m}{26m} = 9.615\ mA/V$ **[1]**

$A_d = \frac{9.615m(20k)}{2} = 96.15\ V/V$ **[1]**

Question 2 [20 marks]

Answers:

Question 2(a) [5 marks]

Option 1:

$$I_Q = \left(\frac{k_n'}{2}\right)\left(\frac{W}{L}\right)_4 (V_{GS4} - V_{TN})^2$$ **[1]**

$$0.2m = \left(\frac{50\mu}{2}\right)(15)(V_{GS4} - 0.5)^2$$ **[1]**

V_{GS4} = 1.23 V, $V_{GS3} = V_{GS4}$ = 1.23 V **[1]**

V_{GS5} = V+ - V- - V_{GS3} = 5 – (-5) – 1.23 = 10 – 1.23 = 8.77 V **[2]**

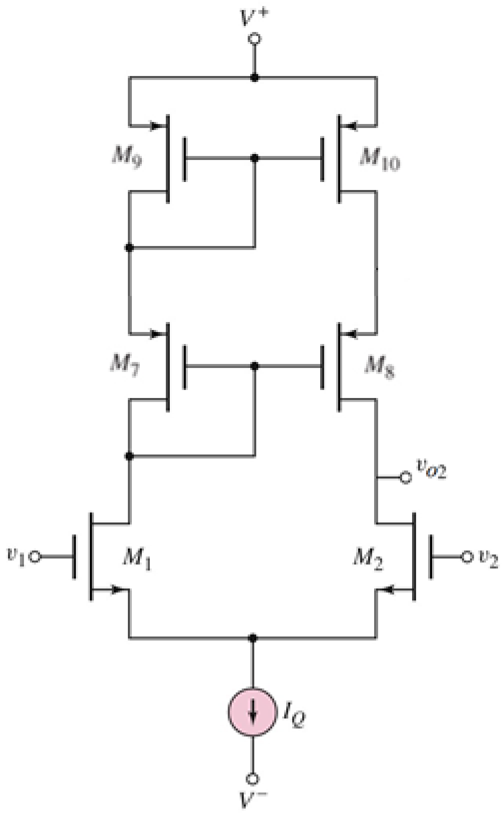
Option 2:

$$I_{D5} = I_{D3}$$ **[1]**

$$\left(\frac{50\mu}{2}\right)(3)(V_{GS5} - 0.5)^2 = \left(\frac{50\mu}{2}\right)(15)(10 - V_{GS5} - 0.5)^2$$ **[3]**

V_{GS5} = 6.72 V **[1]**

Question 2(b) [5 marks]



Power supplies & connections	[2]
NMOS Diff amp	[1]
PMOS Cascode current source	[2]
Total	**[5 marks]**

Question 2(c) **[10 marks]**

Calculate A_d with passive load R_D

$A_d = (g_{m2} R_D) / 2$ **[1]**

$g_{m2} = 2\sqrt{(K_n I_Q/2)} = 2\sqrt{[(0.4m)(0.2m/2)]} =$ **0.4 mA/V** **[1]**

$A_d = (0.4m \times 40k) / 2 = 8$ **V/V** **[1]**

Calculate A_d with Cascode active load

$A_d = g_{m2} (r_{O2} \,||\, R_{OCascode})$ **[1]**

$r_{O2} = 1/(\lambda_n I_Q/2) = 1/ [(0.02)(0.2m/ 2)] =$ **500 kΩ** **[1]**

$R_{OCascode} \approx g_{m8}\, r_{O8}\, r_{O10}$ **[1]**

$g_{m8} = 2\sqrt{(K_p I_Q/2)} = 2\sqrt{[(0.2m)(0.2m/2)]} =$ **0.2828 mA/V** **[1]**

$r_{O8} = 1/(\lambda_p I_Q/2) = 1/ [(0.02)(0.2m/ 2)] =$ **500 kΩ** **[0.5]**

$r_{O10} = 1/(\lambda_p I_Q/2) = 1/ [(0.02)(0.2m/ 2)] =$ **500 kΩ** **[0.5]**

$R_{OCascode} \approx (0.2828m)(500k)(500k) = 70.7\ M\Omega$ **[0.5]**

$A_d = (0.4m)(500k \,||\, 70.7M) = 198.6$ or ≈ 200 V/V **[0.5]**

A_d had increased = 198.6 – **8** =190.6 V/V with Cascode active load. or

A_d had increased = 200 – **8** =192 V/V with Cascode active load. **[1]**

Question 3 [20 marks]

Answers:

Question Q3(a) **[10 marks]**

$$I_{C1} = \frac{\beta}{1+\beta} I_{B2} = \frac{\beta}{1+\beta}\frac{I_{C2}}{\beta} = \frac{I_{C2}}{1+\beta} = \frac{1.2m}{61} = 19.67\ \mu A \qquad [2]$$

$$r_{\pi1} = \frac{\beta V_T}{I_{C1}} = \frac{(60)(0.026)}{19.67\mu} = 79.3\ k\Omega \qquad [1]$$

$$r_{\pi2} = \frac{\beta V_T}{I_{C2}} = \frac{(60)(0.026)}{1.2m} = 1.3\ k\Omega \qquad [1]$$

$$R_i = r_{\pi1} + (1+\beta) r_{\pi2} \qquad [1]$$

$$\rightarrow R_i = 79.3k + (61)(1.3k) = 158.6\ k\Omega \qquad [1]$$

$$r_{\pi3} = \frac{\beta V_T}{I_{C3}} = \frac{(60)(0.026)}{5m} = 312\ \Omega \qquad [1]$$

$$R_o = R_2 \parallel \left[\frac{r_{\pi3} + (R_1 || r_{02})}{1+\beta}\right] \qquad [1]$$

$$r_{02} = \frac{V_A}{I_{C2}} = \frac{\infty}{I_{C2}} = \infty \qquad [1]$$

$$\rightarrow R_o = 5k \parallel \left[\frac{312 + (50k || \infty)}{1+60}\right] = 5k \parallel 825 = 708\Omega \qquad [1]$$

Question Q3(b) **[2 marks]**

- Class A has higher power consumption, lower efficiency than class B. [0.5]
  Class B has highest efficiency but suffers from cross over distortion. [0.5]
- Class AB removes cross over distortion of Class B and, but efficiency of Class AB is lower than Class B. [0.5]
- Class A requires higher biasing current I_{CQ} compared to class AB, and has lower efficiency. [0.5]

Question Q3(c) **[8 marks]**

$i_L = \frac{V_O}{R_L} = \frac{5}{100} = 50\ mA$ [1]

$i_{cn} = i_L = 50\ mA$ [1]

$V_{BEn} = V_T \ln\left(\frac{I_{Cn}}{I_S}\right) = (26m) \ln\left(\frac{50m}{10^{-13}}\right) = 0.7004\ V$ [1]

$V_{EBp} = V_{BB} - V_{BEn} = 1.35 - 0.7004 = 0.6496\text{V}$ [0.5]

$i_{cp} = I_S exp^{V_{EBp}/V_T} = 10^{-13} exp^{0.6496/26m} = 7.0947\ mA$ [1]

Recalculate: $i_{cn} = i_L + i_{cp} = 50m + 7.0947\text{m} = 57.0947\ \text{mA}$ [0.5]

$V_{CEn} = V_{CC} - V_O = 10 - 5 = 5\ V$ [0.5]

$V_{ECp} = V_O - (-V_{CC}) = 5 - (-10) = 15\ V$ [0.5]

$P_{Qn} = i_{cn} V_{CEn} = 57.0947\text{m x } 5 = 285.48\ mW$ [1]

$P_{Qp} = i_{cp} V_{ECp} = 7.0947\text{m x } 15 = 106.42\ mW$ [1]

Question 4 [20 marks]
Answers:

Question Q4(a) **[10 marks]**

Using the equation, $I_C = I_S exp^{V_{BE}/V_T}$ [1]

$V_{BE11} = V_{EB12} = V_T \ln\left(\frac{I_C}{I_S}\right)$ [1]

$V_{BE11} = V_{EB12} = 0.026 \ln\left(\frac{0.4 \times 10^{-3}}{5 \times 10^{-16}}\right) = \mathbf{0.7126\ V}$ [2]

Find R_5 and R_4;

$R_5 = \frac{V^+ - V_{EB12} - V_{BE11} - V^-}{I_{C10}} = \frac{15 - 0.7126 - 0.7126 + 15}{0.4m} = \mathbf{71.44\ k\Omega}$ [2]

$I_{C10} R_4 = V_T ln \frac{I_{REF}}{I_{C10}}$ [1]

$R_4 = \frac{0.026}{0.04m} ln \frac{0.4m}{0.04m} = \mathbf{1.497\ k\Omega}$ [1]

$V_{BE10} = V_{BE11} - I_{C10} R_4 = 0.7126 - 0.04m(1.497k) = \mathbf{0.6527\ V}$ [2]

Question Q4(b) **[10 marks]**

$A_d = g_{m2}(r_{o2} \parallel r_{o4})$ [1]

$g_{m2} = \sqrt{2K_p I_Q} = \sqrt{2(100\mu)(100\mu)} = 141.42\mu A/V$ [1]

$r_{o2} = \frac{1}{\lambda_p I_{D2}} = \frac{1}{0.02x50\mu} = 1M\Omega$ [1]

$r_{o4} = \frac{1}{\lambda_n I_{D4}} = \frac{1}{0.01x50\mu} = 2M\Omega$ [1]

$A_d = (141.42\mu)(1M \parallel 2M) = 94.286$ [0.5]

$A_{v2} = g_{m7}(r_{o7} \parallel r_{o8})$

$g_{m7} = 2\sqrt{K_{n7} I_{D7}} = 2\sqrt{(125\mu)(100\mu)} = 223.6\mu A/V$ [1]

$r_{o7} = \frac{1}{\lambda_n I_{D7}} = \frac{1}{0.01x100\mu} = 1M\Omega$ [1]

$r_{o8} = \frac{1}{\lambda_p I_{D8}} = \frac{1}{0.02x100\mu} = 0.5M\Omega$ [1]

$A_{v2} = (223.6\mu)(1M \parallel 0.5M) = 74.53$ [0.5]

$A_v = A_d A_{v2} = 94.286x74.53 = 7027.45$ [1, 1]

Question 5 [20 marks]
Answers:

Question Q5(a) **[4 marks]**

i)	The input impedances of both the inverting and non-inverting input terminals are infinity	[0.5].
	Since it is an open circuit, current will not flow into the input terminals.	[0.5]
ii)	Since open loop gain Aod is infinity,	[1]
	for a finite output voltage vo, the differential voltage vd = v2-v1 is zero.	[1]
	Hence v1 and v2 are nearly equal, i.e. v1=v2, which is a 'virtual short'.	[0.5]
	Both voltages v1 & v2 are forced to be the same without any physical connection between the terminals	[0.5].

Question Q5(b) **[4 marks]**

$$v_O = \left(1+\frac{R_2}{R_1}\right)v_i = \left(1+\frac{30k}{20k}\right)1m = 2.5\ mV \qquad [0.5, 0.5, 0.5]$$

$$v_{O1} = v_O = 2.5\ mV \qquad [1]$$

$$v_{O2} = -\left(\frac{R}{R}\right)v_O = -\left(\frac{10k}{10k}\right)2.5m = -2.5\ mV \qquad [0.5, 0.5, 0.5]$$

Question Q5(c) **[12 marks]**

$$v_O(max) = 5\text{ V} = A_d(max)\times V_d = 500V_d \qquad [2]$$

$$V_d = V_{i1} - V_{i2} = \frac{v_O(max)}{A_d(max)} = \frac{5}{500} = 0.01\ V \qquad [1]$$

$$V_d = i_{R1}(max)\times(min),\ where\ R_1(min) = R_{1f} \qquad [1]$$

$$0.01 = 10\mu \times R_{1f}$$

$$R_{1f} = 1\ k\Omega \qquad [1]$$

$$A_d = \left(1+\frac{2R_2}{R_{1f}+R_{1v}}\right)\left(\frac{R_4}{R_3}\right),\ where\ \frac{R_4}{R_3} = 4 \qquad [1]$$

$$A_d(max) = 500 = \left(1+\frac{2R_2}{R_{1f}}\right)(4) = (1+\frac{2R_2}{1k})(4) \qquad [2]$$

$$\text{So, } R_2 = 62\ k\Omega \qquad [1]$$

$$A_d(min) = 10 = \left(1+\frac{2R_2}{R_{1f}+R_{1v}}\right)(4) = (1+\frac{2(62k)}{1k+R_{1v}})(4) \qquad [2]$$

$$\text{So, } R_{1v} = 81.67\ k\Omega \qquad [1]$$